Adaptive algorithms for QCSE optical modulators

Excitonic optical absorption at near band gap photon energies in III-V compound semiconductor quantum well structures has very important device applications as optical modulators and detectors. By applying an electric field perpendicular to the plane of the quantum well, the excitonic optical absorption strength and energy can be manipulated. This quantum confined Stark effect (QCSE) requires that electron confinement by the quantum well potential influence electric field dependent absorption. Compared to bulk semiconductors, the excitonic absorption strength in QCSE structures is greater, even in the presence of large externally applied electric field. This performance advantage is the reason why the QCSE has been used to design optical modulators and detectors. Typically, such designs make use of simple rectangular potential wells in the AlGaAs/GaAs or InP/InGaAsP material system. However, conventional ad-hoc approaches to device design do not fully exploit the ability of modern crystal growth techniques to vary the quantum well potential profile on an atomic monolayer scale in the growth direction.

In contrast to the conventional approach, an adaptive design methodology for quantum systems can be used to find a desired target response that is best suited for a QCSE device. The method used is to perform a machine-based search of design space to find the quantum well band edge potential profile that most closely approaches the target response. Because the model of exciton absorption is a two-body effect, the adaptive quantum design algorithm may be thought of as manipulating a two-body wave function to achieve a desired behavior by varying the potential profile.

Fig. 1 illustrates the successful use of our adaptive design methodology to simultaneously maximize excitonic absorption peaks separated in energy by 10 meV at bias voltages $F = 0$ kV/cm and $F = 70$ kV/cm. The significance of this initial proof-of-principle adaptive quantum design result is the predicted superior performance compared to all previous ad-hoc solutions that have emerged over the past 20 years. Fig. 2(a) is a measured comparison of modulator transfer function showing 13 dB extinction for 0.5 V change in applied external potential. A commercial device requires 2.0 V to achieve the same extinction ratio. Fig. 2(b) is a photograph of a DFB laser with emission at 1550 nm wavelength and integrated QCSE modulator used in Fig. 2(a) to illustrate the advantages of device synthesis.

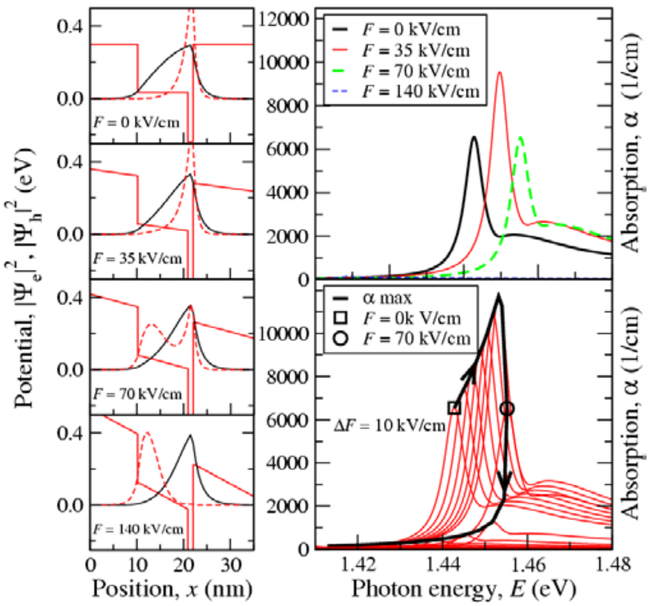
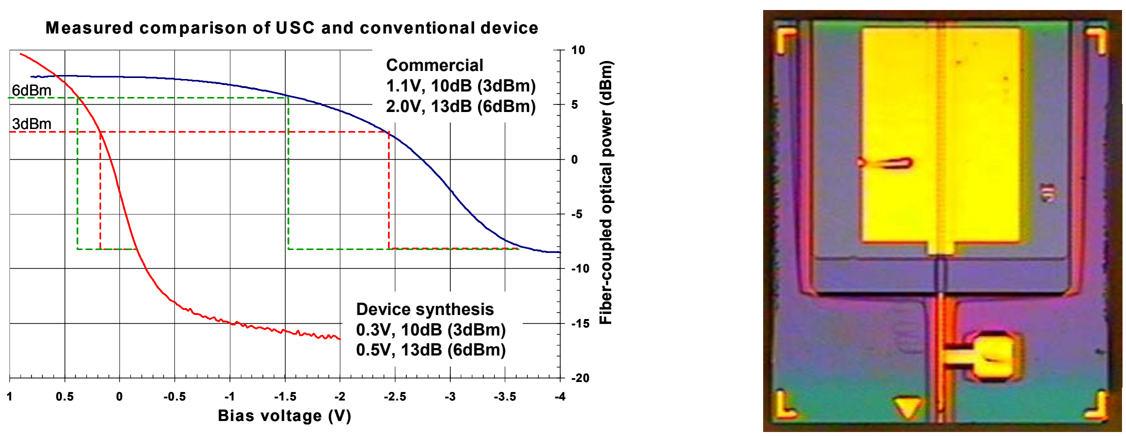


Fig. 1. Illustration of manipulation of electron and hole wave function by varying band edge profile results in optimized QCSE absorption response function. In this example, the target response is an absorption spectrum with maximized, equal-height excitonic peaks at bias voltages F = 0 kV/cm and F = 70 kV/cm which are separated in energy by 10 meV.



(a) (b)

Fig. 2. (a) Measured comparison of modulator transfer function showing 13 dB extinction for a 0.5 V change in applied external potential. A commercial device requires 2.0 V to achieve the same extinction ratio. (b) Photograph of a DFB laser with emission at 1550 nm wavelength and integrated QCSE modulator used in (a) to illustrate the advantages of device synthesis.